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## What is Claimed:

- A laser micromachining system for drilling holes in a work piece 1. 1 comprising: 2 a laser beam generator for directing a laser beam having a wavelength  $\lambda$ , 3 4 along an optical path, an image interpolating mask having an array of apertures, disposed in the 5 optical path, for receiving the laser beam and forming a corresponding array of sub-beams 6 of a first pitch size, 7 a translation stage configured to move the array of sub-beams in a 8 perpendicular direction to the optical path, and 9 a demagnifier, disposed in the optical path, for forming a reduced-size 10 pattern of the array of sub-beams on the work piece, the reduced-size pattern having a 11 second pitch size, 12 wherein the second pitch size is less than  $\lambda$  and the first pitch size is greater 13 than  $\lambda$ , and 14 when the laser beam is generated and the translation stage moves the array 15 of sub-beams, the image interpolating mask is effective in forming an array of holes 16 having the second pitch size. 17 2. The laser micromachining system of claim 1 wherein 1
- the array of sub-beams formed by the image interpolating mask is a subpattern of the reduced-size pattern formed on the work piece, and
- the translation stage is configured to move the array of sub-beams in a sequence to form the reduced-size pattern on the work piece.

1	3. The laser micromachining system of claim 2 wherein
2	the translation stage is coupled to the image interpolating mask for moving
3	the image interpolating mask and the array of sub-beams.
1	4. The laser micromachining system of claim 2 wherein
2	the translation stage is coupled to a work piece holder holding the work
3	piece for moving the work piece with respect to the array of sub-beams.
1	5. The laser micromachining system of claim 1 wherein
2	the array of apertures of the image interpolating mask has an aperture
3	density of 1/N times an image density of the reduced-size pattern on the work piece and
4	times a demagnification factor of the demagnifier, N being a positive integer, and
5	the array of sub-beams is configured to translate N-times in a perpendicular
6	direction to the optical path by the translation stage to form the array of holes of the
7	second pitch size.
1	6. The laser micromachining system of claim 1 wherein
2	the laser beam generator includes a pulsed laser providing a pulsed-on
3	period of less than 200 femtoseconds, and
4	a harmonic generating crystal, coupled to the pulsed laser, for providing a
5	harmonic frequency of the pulsed laser to produce the laser beam having the wavelength
6	of $\lambda$ .
1	7. The laser micromachining system of claim 1 wherein
2	the demagnifier includes a first lens having a first focal length and a
3	microscope objective having a second focal length, and

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4	second focal I		agnification factor resulting from the first focal length divided by the
1		8.	The laser micromachining system of claim 1 wherein
2		each c	of the sub-beams includes a Gaussian intensity distribution, and
3	equal to the f		of the array of holes has a diameter of approximately less than or the thick that half maximum (FWHM) of the Gaussian intensity distribution.
1		9.	The laser micromachining system of claim 1 wherein
2	generator for		ning mirror is provided in the optical path behind the laser beam nly distributing the laser beam onto the image interpolating mask.
1		10.	The laser micromachining system of claim 1 wherein
2		the se	cond pitch size is less than a diffraction limit of the laser beam, and
3	multiplied by		st pitch size is greater than the diffraction limit of the laser beam agnification factor of the demagnifier.
1 2	comprising:	11.	A laser micromachining system for drilling holes in a work piece
3	laser beam ha		r beam generator for directing a laser beam along an optical path, the wavelength of $\boldsymbol{\lambda},$
5 6 7		or recei	action optical element (DOE) and a telecentric f- $\theta$ lens disposed in the ving the laser beam and forming an array of sub-beams, the array of first pitch size,
8 9	perpendicular		slation stage configured to move the array of sub-beams in a on to the optical path, and

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a demagnifier for forming a reduced-size pattern of the sub-beams onto the 10 work piece, the reduced-size pattern having a second pitch size, 11 12 wherein the second pitch size is less than  $\lambda$  and the first pitch size is greater than  $\lambda$ , and 13 when the laser beam is generated and the translation stage moves the array 14 of sub-beams, the DOE and the telecentric f- $\theta$  lens are effective in forming an array of 15 holes having the second pitch size. 16 12. The laser micromachining system of claim 11 wherein 1 the array of sub-beams formed by the DOE and the telecentric f- $\theta$  lens are a 2 sub-pattern of the reduced-size pattern formed on the work piece, and 3 the translation stage is configured to move the array of sub-beams in a 4 5 sequence to form the reduced-size pattern on the work piece. 13. The laser micromachining system of claim 12 wherein l 2 the translation stage is coupled to the telecentric f- $\theta$  lens for moving the telecentric f- $\theta$  lens and the array of sub-beams. 3 14. The laser micromachining system of claim 12 wherein 1 the translation stage is coupled to a work piece holder holding the work 2 piece for moving the work piece with respect to the array of sub-beams. 3 15. The laser micromachining system of claim 11 wherein 1 2 the array of sub-beams has a density of 1/N times an image density of the reduced-size pattern on the work piece and times a demagnification factor of the 3 demagnifier, N being a positive integer, and

5 6	the array of sub-beams is configured to translate N-times in a perpendicular direction to the optical path by the translation stage to form the array of holes of the		
7	second pitch size.		
1	16. The laser micromachining system of claim 11 wherein		
2	the laser beam generator includes a pulsed laser providing a pulsed-on period of less than 200 femtoseconds, and		
4 5 6	a harmonic generating crystal, coupled to the pulsed laser, for providing a harmonic frequency of the pulsed laser to produce the laser beam having the wavelength of $\lambda$ .		
1	17. The laser micromachining system of claim 11 wherein		
2	each of the sub-beams includes a Gaussian intensity distribution, and		
3 4	a hole of the array of holes has a diameter of approximately less than or equal to the full width at half maximum (FWHM) of the Gaussian intensity distribution.		
1	18. The laser micromachining system of claim 11 wherein		
2	a scanning mirror is provided in the optical path behind the laser beam generator for uniformly distributing the laser beam onto the DOE.		
1.	19. The laser micromachining system of claim 11 wherein		
2	the second pitch size is less than a diffraction limit of the laser beam, and		
3	the first pitch size is greater than the diffraction limit of the laser beam multiplied by a demagnification factor of the demagnifier.		
1	20. A laser micromachining system for drilling holes in a work piece comprising:		

3	a laser beam generator for directing a laser beam having a wavelength $\boldsymbol{\lambda}$ ,
4	along an optical path,
5	an image interpolating mask having an array of apertures, disposed in the
6	optical path, for receiving the laser beam and forming a corresponding array of sub-beams
7	of a first pitch size,
8	a translation stage configured to move the array of sub-beams in a
9	perpendicular direction to the optical path, and
10	a demagnifier, disposed in the optical path, for forming a reduced-size
11	pattern of the array of sub-beams on the work piece, the reduced-size pattern having a
12	second pitch size,
	•
13	wherein the second pitch size is less than a diffraction limit of the laser
14	beam, and the first pitch size is greater than the diffraction limit of the laser beam, and
15	when the laser beam is generated and the translation stage moves the array
16	of sub-beams, the image interpolating mask is effective in forming an array of holes
17	having the second pitch size.
18	21. The laser micromachining system of claim 20 wherein
	. the accord which aim is approximately accord to a Dayleigh distance of
19	the second pitch size is approximately equal to a Rayleigh distance of $0.61*\lambda/N.A.$ , where N.A. is a numerical aperture of a lens in the optical path.
20	0.01° A/N.A., where N.A. is a numerical aperture of a lens in the optical path.
21	22. The laser micromachining system of claim 21 wherein
2.	22. The last material by Stant of Claim 22 wherein
22	the second pitch size is approximately equal to 1.5* Rayleigh distance.
23	23. A laser micromachining system for drilling holes in a work piece
24	comprising:

25	a laser beam generator for directing a laser beam along an optical path, the
26	laser beam having a wavelength of $\lambda$ ,
27	a diffraction optical element (DOE) and a telecentric f- $\theta$ lens disposed in the
28	optical path for receiving the laser beam and forming an array of sub-beams, the array of
29	sub-beams having a first pitch size,
30	a translation stage configured to move the array of sub-beams in a
31	perpendicular direction to the optical path, and
22	a demagnifier for forming a reduced-size pattern of the sub-beams onto the
32	
33	work piece, the reduced-size pattern having a second pitch size,
34	wherein the second pitch size is less than a diffraction limit of the laser
35	beam, and the first pitch size is greater than the diffraction limit of the laser beam, and
<i></i>	beam, and the first pitch size is greater than the diffraction limit of the laser beam, and
36	when the laser beam is generated and the translation stage moves the arra
37	of sub-beams, the DOE and the telecentric f- $\theta$ lens are effective in forming an array of
38	holes having the second pitch size.
39	24. The laser micromachining system of claim 23 wherein
40	the second pitch size is approximately equal to a Rayleigh distance of
41	$0.61*\lambda/N.A.$ , where N.A. is a numerical aperture of a lens in the optical path.
42	25. The laser micromachining system of claim 24 wherein
43	the second pitch size is approximately equal to $1.5*$ Rayleigh distance.
44	26. A method of drilling holes in a work piece comprising the steps of:
45	<ul><li>(a) receiving a laser beam directed along an optical path;</li></ul>

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46	(1	b)	directing the laser beam through a beam former, disposed in the
47			optical path, to form an array of sub-beams of a first pitch size;
48	(0	c)	demagnifying the array of sub-beams to form a reduced-size pattern
49			of a second pitch size on the work piece;
50	((	d)	translating the array of sub-beams in a perpendicular direction to the
51			optical path; and
52	(	•	after translating the array of sub-beams in the perpendicular
53			direction to the optical path, forming the reduced-size pattern of the
54			second pitch size on the work piece.
1	2	27.	The method of claim 26 wherein
1	2	.,.	The method of claim 20 wherein
2	S	tep (a	) includes receiving the laser beam having a wavelength of λ;
			,
3	S	tep (b	) includes forming the array of sub-beams with a pitch size greater
4	than the wavele	ength (	of λ; and
5	s	tep (e	) includes forming the reduced-size pattern on the work piece with a
6	pitch size small	er tha	n the wavelength of λ.
1			The method of claim 26 wherein the first pitch size is larger than the
2	•	-	a factor of P times a demagnification factor provided by the
3	demagnifying st	tep, P	being a positive integer; and
	_	A (-1	
4			) includes translating the array of sub-beams in the perpendicular
5	direction P time	es, and	
6	ct	ten (e	) includes after translating the array of sub-beams P times, forming
7			ern of the second pitch size on the work piece.
•		- Face.	2 2. 2 2.2. p. c 5.2. c d. c. Nork piece.
1	2	.9 <b>.</b>	The method of claim 26 wherein

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2	step (b) includes directing the laser beam through an image interpolating
3	mask having an array of apertures, and
4	forming the array of sub-beams after passing the laser beam through the
5	array of apertures.
1	30. The method of claim 26 wherein
2	step (b) includes directing the laser beam through a DOE and a telecentric f- $\boldsymbol{\theta}$ lens, and
3	o lens, and
4	forming the array of sub-beams after passing the laser beam through the
5	DOE and the telecentric f- $\theta$ lens.
1	31. The method of claim 30 including
2	after directing the laser beam through the DOE, forming an angled beam
3	pattern; and
4	forming the array of sub-beams into a parallel pattern by passing the angled
5	beam pattern through the telecentric f- $\theta$ lens.
1	32. The method of claim 26 wherein the array of sub-beams has a
2	density of 1/N times an image density of the reduced-size pattern on the work piece and
3	times a demagnification factor of the demagnifying step, N being a positive integer; and
4	step (d) includes translating the array of sub-beams N times in the
5	perpendicular direction to the optical path; and
6	step (e) includes after translating the array of sub-beams N times, forming
7	the reduced-size pattern on the work piece.
1	33. The method of claim 26 wherein

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- step (d) includes coupling a translation stage to the beam former for translating the array of sub-beams in the perpendicular direction to the optical path.
  - 34. The method of claim 26 wherein

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step (d) includes coupling a translation stage to a work piece holder for translating the array of sub-beams in the perpendicular direction with respect to the optical path.